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GEOPHYSICS.—*Testing a theory of the earth's interior.*[1] REGINALD A. DALY, Harvard University. (Communicated by L. H. Adams.)

The processes responsible for the structure of the visible part of the earth have been controlled by the physical properties of the invisible part. The character of this incomparably greater volume of material presents the most fundamental and important problem of physical geology. How shall it be solved?

Atomic physics and astrophysics are being guided to major discoveries by the testing of models of atoms and models of stars. Geodetic measurements and seismological results are becoming increasingly accurate by the use of theoretical models of the earth. Similarly, physical geology will be advanced by examining the merits of theoretical models of the globe, models constructed in the light of the myriad field and laboratory observations already published. As a result of such synthetic study the writer presented in his book *Igneous Rocks and the Depths of the Earth* of the year 1933 a preferred picture of terrestrial material. Since the manuscript of the book was sent to press new data from seismology, on the radioactivity of rocks, and on thermal gradients in the earth's crust, particularly the gradients given by R. H. Cleland for Pre-Cambrian rocks in Canada, suggest the need of changes of the earth model in detail, but seem to demand no change of principle.[2]

The present paper discusses the validity of this theoretical model with respect to the distribution of strength in the earth's body, as now constituted. The conditions of earlier epochs are not considered. "Strength" is defined as the power to resist the deforming tendency of a shearing stress indefinitely prolonged. The tests of validity form two groups. The first includes those that have been supposed, though apparently without warrant, to prove considerable strength in the deep interior of the planet. The second group give a positive result

[1] Substance of an address to the Geological Society of Washington, April 24, 1935. Received May 15, 1935.

[2] See CLELAND, R. H. Trans. Canad. Min. Inst. 33: 379. 1933.

and indicate extreme weakness in all of the earth-shells beneath a comparatively thin crust.

A MODEL OF THE EARTH

Essential characteristics of the earth-shells, according to the preferred picture of 1933, are summarized in the following table.

TABLE 1.—CHARACTERISTICS OF THE EARTH-SHELLS

Earth-shell	Average thickness (km.)	Average density	Temperature (approximate)	Reaction to shear-stress	Strength
1. Crystalline crust: *a.* Continental segment	Circa 60	2.89	10°–1350°C.	Elastic	Considerable
b. Suboceanic (deep-Pacific) segment	Circa 75	3.03	1°–1400°	Elastic	Considerable
2. Vitreous, basaltic substratum	? (probably less than 400 km.)	2.80–2.85 at top	1350°–1400° at top	Elastico-viscous	Vanishingly small
3. Vitreous silicate shell, more basic than 2	Ca. 2300	Ca. 3.5–6.5	?	Elastico-viscous	Vanishingly small
Major discontinuity 4. Core, probably metallic iron	Ca. 3500	Ca. 10.5–12.5	?	Elastico-viscous or fluid	Vanishingly small

Elastico-viscosity for the subcrustal shells is assumed: first, because the assumption seems to offer the only means of reconciling the high rigidity proved by the seismologist with the degree of isostasy proved by the geodesist; secondly, because the exalted temperature of those shells means thorough atomic agitation, and consequent instability of any space-lattice in the aggregations of atoms. The decay of rigidity may follow Maxwell's law, involving the first power of the stress-difference. However, when the stress-difference becomes extremely small, the law followed may be that of Adams and Williamson, involving the square of the stress-difference.[3] If the average time of relaxation were as much as 100 years, the stress-difference would become immeasurably small during a small fraction of a geological period. This whole idea, that most of the earth's body behaves under shearing stress like pitch, is of course not new to science.

[3] MAXWELL, J. C. Phil. Mag. 35: 134. 1868; ADAMS, L. H., and WILLIAMSON, E. D. Jour. Franklin Inst. 190: 619, 631. 1920.

OBJECTIONS TO ASSUMING AN ELASTICO-VISCOUS INTERIOR

1. The first argument against the validity of the model is based on clear proofs of high rigidity of the whole silicate shell of the earth, with respect to small stresses of short periods. Seismic and tidal waves give such stresses, and their propagation is so perfect that associated, non-elastic displacements, if real, are too small for measurement. On the other hand, Jeffreys has found that even the small stress-differences set up during the cycle of the variation of latitude appear to be accompanied by some plastic yielding of the earth's body. He has explained the apparent fact by supposing the subcrustal material to be elastico-viscous, with a time of relaxation of rigidity equal to about ten years.[4] Jeffreys' discussion is only one illustration of the manifest fact that rigidity has no necessary connection with strength.

The high rigidity, effective in all such cases of slight, periodic stressing, is regarded as a derivative of viscosity, enormously increased by the intense hydrostatic pressure exerted on subcrustal material. This explanation, though prompted by analogies found in Bridgman's experiments on the viscosity of organic liquids at high pressures, is frankly speculative and to be suspected until the results of more direct experimentation are in hand.[5] However, the combination of great rigidity and non-crystallinity in earth-shells below the depth of 80 kilometers or so is assumed partly for a quite different reason: that this hypothesis appears best to account for the major displacements of, and in, the earth's crust. Both lines of argument are manifestly subject to doubt, and the writer fully realizes the need of better geophysical support for this basal assumption regarding the connection between rigidity and the state of the earth's materials.

2. From deflection residuals and gravity anomalies Clarke, Helmert, Berroth, and Heiskanen deduced an elliptical form for the geoid in the plane of the equator. In other words, these authors were led to propose a triaxial ellipsoid as the approximate "figure of the earth." Heiskanen's calculations gave a difference of about 500 meters between the major and minor axes of the geoid at the equator. This would mean for the solid surface of the earth an equatorial ellipticity of about 1000 meters.[6]

[4] JEFFREYS, H. *The Earth*, 2nd ed., Cambridge, Eng., p. 266,1929.

[5] BRIDGMAN, P. W. Proc. Amer. Acad. Arts and Sciences, 61: 96. 1926; *The Physics of High Pressure*, New York, chap. 12, 1931.

[6] HEISKANEN, W. *Gerlands Beitraege zur Geophysik*. 19: 356, 1928, with references to the earlier writers; cf. JEFFREYS, H. *The Earth*, 2nd ed., Cambridge, Eng., p. 222,1929.

Since geology knows no reason why the corresponding stresses could have been developed in recent geological time, the deduced triaxiality would mean practical strength at great depth. Yet there are several grounds for doubting the hypothesis of triaxiality. The number and distribution of gravity stations are still inadequate for solution of the problem. Its data are imperfect until our present ignorance of the correct basis for reducing the field observations of gravity is dispelled. The values of gravity found by Vening Meinesz in the extensive West Indian and East Indian regions do not agree with any triaxial formula.[7] After all, as Jeffreys points out, the hypothesis of triaxiality reduces deflection residuals and gravity anomalies only a few per cent. And, finally, the hypothesis ill accords with the ice-cap proof of minute or zero strength for the deeper earth-shells.

3. The Moon is elliptical in its equatorial section, the major and minor axes of the ellipse being found to differ by approximately 500 meters. The inequality, regarded as a frozen tide that was raised when the moon was much nearer the earth than it is at present, means notable stress-differences at relatively great depth below the surface. These stresses have been resisted for more than a billion years. Hence the lunar material at the depth concerned must have practical strength. Jeffreys has argued that the earth is homologous, of qualitatively similar properties.[8] However, there is good reason to believe: that the moon has cooled much faster than the earth, which is fifty times larger in volume and of mass eighty times larger; and hence that the moon early became crystallized to a far greater relative depth, if not to its actual center. Also in view of the low value of gravitation by the moon, it seems legitimate to explain the observed inequality of the lunar figure by the strength of crystallized rock; it is equally legitimate to question the argument for strength in the deeper earth-shells so far as this argument is based on an assumed homology between planet and satellite.

4. Many earthquakes have been shown to have originated around focal points from 100 to 700 kilometers below the earth's surface. As yet seismologists are unable to understand why seismic blows can be struck at such depths. The reality of the deep foci seems to add one more argument against the idea that the earth-shell involved is utterly weak. The question whether the shocks imply solid-elasticity or elastico-viscosity awaits an answer. In either case brittleness and

[7] See HEISKANEN, W. Gerlands Beitraege zur Geophysik, 36: 197. 1932; VENING MEINESZ, F. A. *Gravity at Sea*, Netherlands Geodetic Commission Pub. 2: 109. 1934.
[8] JEFFREYS, H. *The Earth*, 2nd ed., p. 229,. 1929.

sudden slips of the deep material are conceivable. Indeed the phenomena connected with the isostatic deformation of the earth's crust in response to unloading with deglaciation appear best explained by assuming spasmodic, vertical shears to depth of the order of 1000 kilometers. (See below.) However, these sudden displacements affect zones which in ground plan are thousands of kilometers long, and there is no obvious reason why the movements should cause specially energetic shocks at "points" in the zones. The same difficulty appears when the analogous mechanism of isostatic adjustment between erosionally unweighted continent and weighted sea-floor is studied. Probably the answer to the question will come when seismologists thoroughly understand why displacements along rifts at the surface and hundreds of kilometers long are accompanied by the actual, highly localized shocks. Pending further investigation it seems right to hold that the discovery of deep seismic foci does not disprove the rule of elastico-viscosity at depths exceeding 100 kilometers.

5. The existence of peneplains has been thought to demonstrate strength for the deeper earth-shells. According to the argument the earth's crust remains unmoved while heavy loads of wide spans are removed by secular erosion. During those millions of years isostasy is supposed to fail in each peneplained region, and stresses of some magnitude are supposed to reside in the material far below the surface. However, no proof of such significant departure from isostasy for any extensive peneplained area has yet been produced. In the United States as elsewhere many peneplained areas have kept nearly the same relation to their baselevels as they had during the removal of matter, and nevertheless exhibit no systematic gravity anomalies of negative character.

Further, the upwarping of peneplained surfaces does not necessarily mean previous failure of isostasy. The strongest warping is found in orogenic belts, where mountain-roots have been sunk deeply into the earth's body. Thus the isotherms were depressed. Their restoration to their original levels has taken millions of years. It seems fair to assume expansion of the material beneath the visible mountain-structure, and enough delay in the expansion to cause warping of a surface already peneplained. Then there is a second possibility, the slow heating and expansion of mountain roots by radio-activity. Whatever the cause, the upwarping of any peneplain can not be considered a priori evidence of important lack of isostatic balance in the region at any stage of its erosional history.

6. Because individual plus and minus areas of gravity anomaly appeared to have spans of 1000 or more kilometers, Barrell and Jeffreys attributed strength to the material at depths of hundreds of kilometers. For example, from the 1912 anomaly map of the United

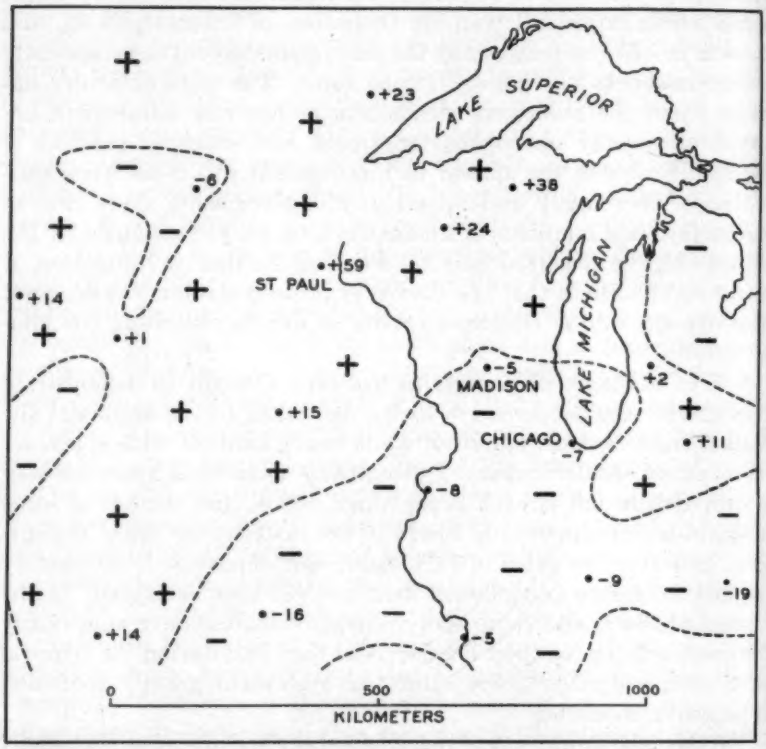


Fig. 1.—Isostatic anomalies (in milligals) and (broken) lines of zero anomaly, separating plus and minus areas. Computations based on 18 stations and on the corrected Helmert 1901 formula for the figure of the earth; Pratt-Hayford depth of compensation assumed to be 113.7 kilometers. (Special Publication No. 10, U. S. Coast and Geodetic Survey, Illustration No. 2, 1912.)

States (89 gravity stations) Barrell supposed one such area to have a width of 2800 kilometers, and a maximum departure from isostasy measured by the weight of 380 meters of rock. He therefore concluded that the earth-shells at depths exceeding 500 kilometers could permanently support decided stress-differences. From the data of the 1917 anomaly map, including measurements at 130 additional stations, Jeffreys came to a similar conclusion. However, as more and

more gravity stations in the United States are occupied, the areas characterized by anomalies of one sign tend to decrease to a notable extent. Some illustrations will make this important fact clear.[9]

a. On the 1912 map eight plus areas and four minus areas were

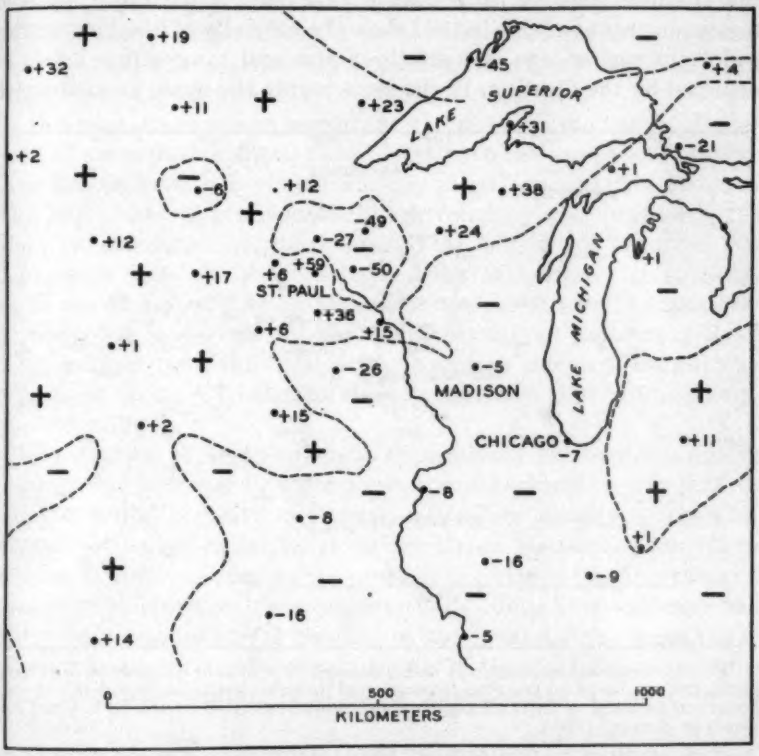


Fig. 2.—Isostatic anomalies (in milligals) and lines of zero anomaly in the same area as that shown in Fig. 1. Computations based on 41 stations; otherwise as in the case represented by Fig. 1. (Special Publication No. 40, U. S. Coast and Geodetic Survey, Illustration No. 11, 1917.)

contoured in the United States; on the 1917 map, thirteen plus areas and eight minus areas; on the map of 1924, seventeen plus areas and seven minus areas.

b. The wide plus area shown on the 1912 map west and southwest

[9] See BARRELL, J. Jour. Geology, 23: 30 ff. 1915; JEFFREYS, H. *The Earth*, 2nd ed., p. 201,1929; HAYFORD, J. F., and BOWIE, W. U. S. Coast and Geod. Survey, Spec. Pub. 10, Illustration no. 2 (anomaly map) 1912; BOWIE, W. ibid., Spec. Pub. 40, fig. 13 (anomaly map), 1917; and ibid., Spec. Pub. 99, fig. 7 (anomaly map),1924; *Principal Facts for Gravity Stations in the United States*, with map, issued by the U. S. Coast and Geodetic Survey, 1934.

of the Great Lakes (Fig. 1) was greatly narrowed on the 1917 map (Fig. 2), after only a relatively small addition to the field data.

c. The region covered by Figure 3 was, on the 1917 map, marked as characterized by positive anomalies, except for the small part at the northwest corner, indicated by the stipple pattern. The field measurements available in 1934 show the necessity of breaking up this wide plus region into at least three plus and three minus areas, as depicted by the drawing. In the same region the mean anomaly with

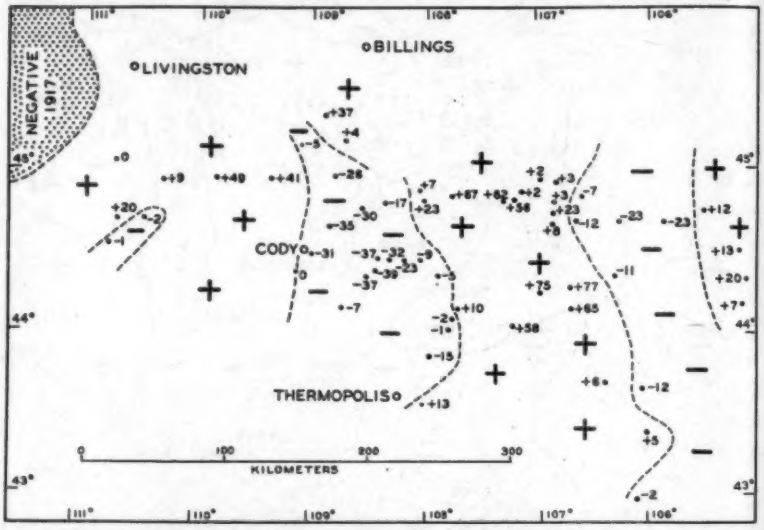


Fig. 3.—Isostatic anomalies (in milligals) and lines of zero anomaly in Wyoming. Computations based on the 1930 International formula; Pratt-Hayford depth of compensation assumed to be 113.7 kilometers. (Data circularized by the U. S. Coast and Geodetic Survey, 1934.)

regard to sign was, according to the facts known in 1917, +28 milligals; according to the fuller data of 1934, it is +14 milligals. Evidently the region is more nearly in perfect isostatic adjustment than had been thought.

d. In 1934 twelve stations in northwestern Texas (Nos. 408–419 inclusive) were reported. Eight show plus anomalies and four minus anomalies, with a mean anomaly with regard to sign of +7 milligals. On the 1917 map the whole of the same region was marked with negative anomaly.

e. Central Kansas, between the meridians of 96°30′ and 100° W. Long., was mapped in 1917 as belonging entirely to an area of positive

anomaly, but the values of gravity reported in 1934 give in the same region two negative belts and an intervening positive belt.

f. On the 1917 map the State of Connecticut appears as a region of negative anomaly; the great majority of the new stations, reported in 1934, give positive anomalies, with mean of +22 milligals.

g. Similarly, qualitative and quantitative changes have been compelled in the Chesapeake Bay region because of the addition of the 1934 data to those of 1917.

However, there is one important exception to the rule of diminution of anomalies in the United States with the increase of stations. The Pacific coast belt of continuously negative anomalies, shown on the 1917 map, is not essentially narrowed by the addition of the data from stations occupied later. This belt is not far from 1000 kilometers wide and extends beyond the actual coast to some line to be drawn east of Vening Meinesz's stations at sea. The maximum anomaly on land south of the Columbia River (data of 1934) is −83 milligals and the mean with regard to sign is −20 milligals. The mean anomaly for the stations at sea, just off the California coast, is +20 milligals.

Explanation of these apparent departures from isostatic equilibrium is not obvious. Bowie regards the departures as not real and attributes the negative anomalies to the low density of the more superficial rock formations along the coast. Heiskanen has offered a quite different solution to the problem in terms of the Airy theory of isostasy.[10] Neither of these experts finds compelling evidence that there is actual failure of isostasy in the coastal belt. Some failure there may be, merely because this part of the earth has not yet had time to reach equilibrium after its late-Tertiary, Cordilleran disturbance.

The problem raised by the wide coastal belt is baffling, but the writer still believes that the study of gravity values in the United States does not prove the existence of rock loads too great to be borne by the strength of the crust alone.

In review, it appears that each of the six objections to the idea of almost or quite perfect weakness for all earth-shells below a level not more than 100 kilometers down from the surface lacks cogency. Attention will now be drawn to the affirmative tests, three in number. All will be presented merely in outline.

[10] BOWIE, W. *Investigations of Gravity and Isostasy*. U. S. Coast and Geod. Survey, Spec. Pub. 40: 76. 1917; HEISKANEN, W. Annales Acad. Scient. Fennicae. 36 (3): 128. 1932.

AFFIRMATIVE TESTS

1. A somewhat detailed discussion of the first appears in the writer's book *The Changing World of the Ice Age*.[11] There it was shown that each principal Pleistocene ice-cap caused both elastic and plastic deformation of the globe, the result being delayed but ultimately close isostatic adjustment for the load of ice. After the melting of each great cap, with corresponding removal of superficial load, isostatic adjustment in the reverse sense has progressed so far that the residual stress-differences in the earth are all extremely small. Nevertheless the adjustment still continues, indicating vanishingly small strength for the material that has been, and is, flowing. Further, there is evidence that, while the horizontally directed flow may be distributed through all depths, it has been concentrated largely below the 1000-kilometer level. If so, the weakness of the deep interior must be nearly or quite absolute.

2. The second test is based on an assumption: that the earth's internal weakness is due to temperature so high as to prevent crystallization at all depths greater than about 75 kilometers below the surface. According to the facts of geology and petrology the uppermost layer of the non-crystalline or vitreous material is best regarded as of basaltic composition, and is conveniently called the basaltic substratum. The layer immediately above—the lower part of the earth's crust—has the elastic properties reasonably assigned to basalt, when crystallized under pressure greater than 10,000 atmospheres. There the velocities of earthquake waves probably exceeds the velocities in the vitreous material just beneath. If so, the time-distance curve of the seismic waves should exhibit the discontinuity that goes with a "shadow zone," analogous to that well established and explained by the sudden drop in velocities at the transition from the earth's silicate shell to her "iron" core. In fact at epicentral distances between about 1000 kilometers and 1700 kilometers there is no strong seismographic record of longitudinal or transverse waves that have penetrated the substratum. For stations at these distances from epicentra the seismograms give no record at all for the waves described, or else record very weak impulses from them. The existence of these slight impulses may be attributed to diffraction along the discontinuity. The theory of the shadow zone here considered will soon be discussed in printed form by the writer's colleague, Dr. L. D. Leet. The reality of the zone has already been suggested by B. Gutenberg.[12] Seismologists will do well to examine still more carefully

[11] Yale University Press, Chapter 4, 1934.

the evidence for the shadow zone and the corresponding change of state at moderate depth in the earth.

3. The remaining test is this: How does the suggested model of the earth *work* with respect to the major problems of petrogenesis, orogeny, and crust-warping? In the writer's opinion this model offers more and better solutions to these problems than any other yet imagined, and is therefore worthy of further testing in the field and laboratory.

CHEMISTRY.—*The development of thermochemistry.*[1] FREDERICK D. ROSSINI, National Bureau of Standards.

Thermochemistry may be defined as that branch of chemistry which treats of the changes in *intrinsic energy* or *heat content* associated with chemical reactions.

The first quantitative measurement of the heat evolved in a chemical reaction was made some years before 1800, and, in the early years of the science, contributions to thermochemistry were made in France, Great Britain, and Russia, by chemists who were famous for other accomplishments as well: Lavoisier, Dalton, Davy, Despretz, Hess, Dulong, Graham, and Andrews.

While these first measurements in thermochemistry were very crude as judged by our present day standards, nevertheless great credit is due these pioneers for their work and for their insight into the meaning of their experimental results. Even at that early day, these investigators sensed the idea that the heat energy associated with a given reaction was in some way related to the chemical activity of the substances concerned. Before 1850, there were extant in the literature data of varying degrees of accuracy on the heats of a large variety of chemical reactions: heats of solution of salts and of their hydrates in water; heats of neutralization of acids and bases in aqueous solution; heats of combustion of gases and of metals in oxygen; heats of direct combination of metals with non-metals.

Soon after 1850, several things occurred which were destined to raise thermochemistry to a very high place. The first of these happenings was the general acceptance of the first law of thermodynamics, and the other was the arrival into the field of thermo-

[12] GUTENBERG, B. Gerlands Beitraege zur Geophysik, **17**: 364. 1927; MÜLLER-POUILLET, *Handbuch der Physik*, **5**: 670. 1928; Bull. Seism. Soc. America. **21**: 216. 1931.

[1] An address delivered before the Chemical Society of Washington, March 14, 1935, on the occasion of the award of the Hillebrand Prize for 1934. Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce. Received May 3, 1935.

chemistry of Julius Thomsen, a Danish chemist at Copenhagen, and of Marcellin Berthelot, a French chemist at Paris.

These two investigators independently announced the same principle relating heat of reaction with chemical affinity, stating that the heat of a given reaction was a direct measure of the chemical affinity of the substances concerned, and that only those reactions would proceed which were accompanied by an evolution of heat energy. Spurred on by their profound belief in the validity of this direct relation between heat content and chemical affinity, Thomsen and Berthelot amassed an enormous amount of data on heats of reaction. Each made notable contributions to the technic of calorimetry. Thomsen developed a reaction vessel for measuring the heats of combustion of gases at constant pressure; Berthelot developed a reaction vessel for measuring the heats of combustion of organic liquids and solids in a closed bomb. Other chemists of the day became imbued with the enthusiasm of Thomsen and Berthelot for the importance of data on heats of reaction, and thermochemistry assumed a lofty place in the science reaching its peak at about the time of the publication of Thomsen's monumental four volumes of thermochemical data in 1882–1886.

By this time, however, the second law of thermodynamics had come into chemistry, and its true relation to chemical reactions was being developed by Clausius, Gibbs, Helmholtz, Van't Hoff, and others. It was shown that the true measure of the chemical affinity of a substance was not its heat content, but a quantity (which we now call free energy) differing from the heat content by a term involving the product of the entropy and the absolute temperature.

Before the close of the century, both Thomsen and Berthelot accepted the second law of thermodynamics, and acknowledged that the heat of reaction alone was only an approximate measure of the chemical affinity, and that in some cases their old principle yielded completely erroneous results. A decline in the work of thermochemistry then set in, and investigators turned their attention to those measurements which would yield true values of chemical affinity or free energy. In the three decades following 1900, researches in thermochemistry were, with a few notable exceptions, sporadic and casual, and our main body of thermochemical data remained those of Thomsen and Berthelot.

About 1906, Nernst pronounced this famous heat theorem, which, with certain limitations, became accepted as the third law of thermodynamics. The third law made possible the determination of en-

tropies by measurement of heat capacities down to low temperatures, near the absolute zero, and combination of these values of entropy with data on heats of reaction yielded values of the changes in free energy. The full power of the third law, particularly with regard to organic substances, was soon appreciated, and a great number of these entropy data were obtained. But it was soon found that the existing data on heats of reaction were not comparable in accuracy with the data on entropies, and that the uncertainties in the resulting values of free energy were practically equal to the uncertainties in the data on heat content. This was no reflection upon the work of Thomsen, Berthelot, and their coworkers, whose values more than satisfied the requirements of the 1880's, but it indicated a real need for new and accurate data on heats of reaction.

About 10 years ago, a new and powerful tool for chemical thermodynamics was developed. This was the use of spectroscopic data on the energy levels of gaseous molecules for calculating very accurate values of entropy. These values of entropy were combined with data on heats of reaction to obtain values of the changes in free energy. But, in order to obtain the full benefit of the accurate spectroscopic values of entropy, it was necessary that data on heats of reaction be of the highest possible accuracy. Thus arose another real need for new and accurate thermochemical data.

Again about 10 years ago, the theoretical physicists and chemists began applying the new mechanics to the calculation of the energies of the atomic linkages in molecules. In order to correlate and check the calculations of their theories, accurate data on heats of formation were required. And so arose a third real need for new and accurate values of heats of formation.

Thus, about a decade ago, the stage was set for a renaissance in thermochemistry. One of the first to sense this need and to promote a renewed interest in thermochemical measurements was the late E. W. Washburn, who, as editor-in-chief of the International Critical Tables, was in a particularly good position to appreciate the inadequacy of the existing data.

Though many new thermochemical values have been obtained in the past few years, chiefly in the United States and Germany, we still depend upon many of the data obtained half a century ago. It should be pointed out that Thomsen, Berthelot, and their coworkers had not the advantages of our modern calorimetric apparatus and technic, nor of our pure substances, and therefore the value of their work should not be judged on the basis of present day accuracy. Fifty

years ago, an accuracy of 1 part in 1000 was as remarkable in calorimetry as is 1 part in 10,000 today. It can be said, in general, that the accuracy requirements of thermochemical data have increased about tenfold in the past half century.

Today, the problem of obtaining a reliable value for the heat of a given reaction resolves itself into two parts: First, one must investigate the purity of the given reaction as it proceeds under the conditions of the calorimetric experiment, and determine to what extent, if any, side reactions occur. In the time of Thomsen and Berthelot, because of the less rigid requirements of accuracy, the purity of the calorimetric reaction was not investigated as fully as it is today. Second, one must measure the heat of the reaction in terms of a fundamental unit of energy. As recently as twenty years ago, the accepted calorimetric unit of energy, called the calorie, was defined in terms of the heat capacity of water. From the standpoint of chemical thermodynamics, this calorie was not a satisfactory unit of energy, but it was then the only practical one available. Today, we make our measurements in terms of a fundamental unit of electrical energy, the joule. We do also report our thermochemical values in calories, but these calories are obtained from the fundamental joule by means of an arbitrarily defined factor, and the resulting defined calorie bears no relation, except incidentally and historically, to the heat capacity of water.

The principle of the modern calorimetric method for measuring heats of reaction is to compare the heat evclved by a measured amount of chemical reaction with the heat evolved by a measured amount of electrical energy, using the calorimeter as the comparator for the two kinds of energy. In this substitution method, the calorimetric conditions are made practically identical in the two kinds of experiment, so that many of the common calorimetric errors are eliminated.

The ultimate end of experimental thermochemistry is the assembly of a table of values from which one may calculate accurately the heat of every one of the infinite number of theoretically possible chemical reactions. Fortunately, it is not necessary to measure the heat of every possible chemical reaction in order to compile such a table, but only to determine the heat of formation, from its elements, of every chemical substance. The determination of the heat of formation of a substance from its elements requires only the measurement of the heat of a reaction in which all the reactants and products, except the given substance, are substances whose heats of formation,

from their elements, are known. Actually, in order to know the heats of formation of 10,000 chemical compounds, including hydrocarbons, it is necessary to measure the heats of less than 10,000 different reactions, because of a simplifying rule for some of the higher hydrocarbons. With these 10,000 values, one can calculate the heats of many, many times that number of chemical reactions.

Fortunately for the peace of mind and the economic security of investigators in thermochemistry, the possibility of the complete compilation of the ultimate table of heats of formation is extremely remote, because, with the passing of time, some values are continually becoming obsolete with respect to accuracy, and furthermore, many new compounds whose heats of formation must be determined are continually being synthesized or discovered by the organic and inorganic chemists.

PALEONTOLOGY.—*Descriptions of Paleozoic fossils from the Central Basin of Tennessee.*[1] R. S. BASSLER, U. S. National Museum.

In a volume entitled "The Stratigraphy of the Central Basin of Tennessee," published in 1932 as Bulletin 38 of the Division of Geology of the State of Tennessee, the writer included plates illustrating the characteristic fossils of the various Paleozoic formations discussed. Among these guide fossils were forty-one new species of invertebrates and algae for which there was no place for their description in the text, although in the explanation of the plates the exact horizon and locality were given in addition in some instances to comparisons with well known forms. This stratigraphic volume was in press for several years, during which time the rules of nomenclature were changed so as to disallow the recognition of species figured but unaccompanied by descriptions. This article is issued to remedy this deficiency in the present case. For economy, the citations to the Tennessee volume are restricted to noting the plate and figure in parenthesis after each of the species. The types of all the following species are the property of the U. S. National Museum.

Solenopora compacta cerebrum Bassler, 1932 (pl. 12, figs. 1, 2)

This common widespread Ordovician alga is represented in the Hermitage formation by large, much convoluted masses resembling a brain, for which reason the varietal name *cerebrum* was proposed. Careful study of this

[1] Published by permission of the Secretary of the Smithsonian Institution. Received May 29, 1935.

genus will probably show the present variety to be worthy of specific standing.

Trenton (top of Hermitage): 6 miles northwest of Carthage, Tenn.

Buthotrephis inosculata Bassler, 1932 (pl. 9, fig. 3)

A fucoid alga consisting of rounded, slightly flattened stems 6 to 8 mm. in diameter, branching dichotomously in the same plain at intervals averaging 30 mm., and also penetrating limestone layers several feet thick until they are completely occupied with these remains.

Black River (Tyrone formation): Hoover's Mills, west of Woodbury, Tenn.

Licrophycus libana Bassler, 1932 (pl. 5, fig. 9)

This fucoid occurs so often on limestone surfaces in spreading, fanshaped fronds arising from a simple stem which by repeated division expands to a diameter of 50 mm. and often overlying each other so that it must represent the remains of a definite organism instead of inorganic markings as regarded by some authors. Although closely related to the type of the genus, *L. ottawense* Billings, the present species is distinguished by its smaller, narrower, shorter, more frequently dividing stems.

Stones River (Lebanon limestone): 2 miles south of Murfreesboro, Tenn

Camarocladia gracilis Bassler, 1932 (pl. 8, fig. 4)

This primitive spongelike organism of uncertain classification is distinguished from the genotype, *C. dichotoma* Ulrich and Winchell, by its stouter, less regularly dividing branches. *C. rugosa* Ulrich, a related species, is still unfigured and all the fossils of this nature require more study.

Black River (Tyrone limestone): Near Dixon Springs, Tenn.

Camarocladia implicatum Bassler, 1932 (pl. 5, fig. 10)

Similar to the preceding in general characters but differing in that the branches are 5 mm. wide, divide at intervals of 15 or more mm., and form a closely matted mass.

Stones River (Lebanon limestone): Lebanon, Tenn.

Saccospongia massalis Bassler, 1932 (pl. 15, figs. 3, 4)

Sponge forming masses of 160 or more mm. in height and width, composed of frequently dividing, closely united branches about 15 mm. in diameter, each with a central canal 7 or 8 mm. wide and with the usual porous structure of *Saccospongia* visible at the surface, three of the pores occurring in 10 mm.

Trenton (Cannon limestone): 2 miles east of Hartsville, Tenn.

Saccospongia laxata Bassler, 1932 (pl. 15, figs. 1, 2)

A branching sponge similar to *S. danvillensis* Ulrich in growth, but differing in the much larger pores of its network, 4 occurring in 10 mm. longitudinally in contrast to 7 of the mentioned related species.

Trenton (Cannon limestone): Near Carthage, Tenn.

Cryptophragmus arbusculus Bassler, 1932 (pl. 16, fig. 9)

Hydrozoon with the transverse partitions and other internal structure

of *C. antiquatus* Raymond, the genotype, but with a stout, frequently branched colony, the branches averaging 10 mm. in diameter.

Trenton (Cannon limestone): 4½ miles east of Hartsville, Tenn.

Tetradium? carterensis Bassler, 1932 (pl. 7, figs. 2, 3)

Coral of solid cylindrical stems, 30 to 40 mm. in diameter, composed of somewhat flattened corallites about 2 mm. in their longer diameter, showing a tendency to imbricate. No septa observed; generic position doubtful.

Black River (Carters limestone): 2 miles southeast of Priest, Tenn.

Tetradium saffordi Bassler, 1932 (pl. 19, fig. 2)

Colony a reticulate mass made by cells having the characteristic 4 septa and arranged in chainlike unilinear or bilinear rows uniting so as to form broad meshes 20 mm. in diameter.

Trenton (Cannon limestone): 2 miles east of Milton, Tenn.

Tetradium laxum Bassler, 1932 (pl. 18, figs. 10–12)

Corallite with septal structure of *Tetradium*, forming masses 70 or more mm. in diameter consisting of loosely growing single tubes each about 1 mm. in diameter, sometimes isolated but often adhering in unilinear sheets, all forming an open network with meshes averaging 7 mm. in width.

Trenton (Cannon limestone): 2 miles east of Hartsville, Tenn.

Tetradium ulrichi Bassler, 1932 (pl. 19, fig. 1)

Like *T. saffordi* Bassler in general growth and structure, but meshes are only about half as broad.

Trenton (Cannon limestone): 2½ miles northwest of Woodbury, Tenn.

Columnaria [alveolata] minor Bassler, 1932 (pl. 11, figs. 1, 2)

Corallum small, composed of polygonal thin-walled corallites in close contact, 2½ mm. wide when mature, each with a primary set of 12 septa extending well towards the center and a shorter secondary set. The small corallites distinguish this species which was figured as a variety, since 5 mm. is the average width in *C. alveolata*.

Trenton (Basal Hermitage): 1 mile south of Belfast, Tenn.

Nyctopora [Columnaria] crenulata Bassler, 1932 (pl. 13, figs. 3, 4)

Corallum of small, rounded masses composed of polygonal thin-walled corallites in close contact, with 5 to 6 in 6 mm., each corallite with 8 primary septa extending a short distance into the tubes and a set of shorter secondary septa. Tabulae in two zones, a crowded one where two occur in a tube diameter, and the other where they are spaced on an average of a tube diameter apart. No mural pores.

Trenton (top of Hermitage): 4 miles south of Carthage, Tenn.

Lichenaria globularis Bassler, 1932 (pl. 13, figs. 1, 2)

Small globular masses, composed of polygonal, thin-walled corallites with 8 to 9 in 6 mm., without septa or mural pores. Tabulae developed at intervals of twice the tube diameter in the uncrowded zone, but in the other zone 2 or 3 occur in the same space.

Trenton (top of Hermitage): 6 miles northwest of Carthage, Tenn.

Lichenaria grandis Bassler, 1932 (pl. 12, figs. 7, 8)

Similar to *L. globularis* but more massive and with larger corallites, of which there are 6 in 6 mm. Septa absent; tabulae present and spaced as in the previous species.

Trenton (top of Hermitage): Near Bradyville, Tenn.

Enopleura punctata Bassler, 1932 (pl. 18, fig. 9)

This well marked cystid is distinguished from the genotype, *E. balanoides* (Meek) by its flattened theca and especially by its highly punctate surface.

Trenton (Cannon limestone): ½ mile north-northeast of Pulaski, Tenn.

Scolithus columbina Bassler, 1932 (pl. 16, fig. 8)

Type specimen a piece of fine-grained dove limestone pierced by worm borings, tubes about 0 5 mm. in diameter filled by crystalline calcite and spaced at intervals of several mm. The minuteness of the borings distinguish this from all other species.

Trenton (base of Cannon limestone): Near Franklin, Tenn.

Amplexopora convoluta Bassler, 1932 (pl. 12, figs. 3, 4)

Bryozoan zoarium, a convoluted mass of 40 or more mm. in diameter, made up of closely intertwining branches composed of angular zooecia with the wall and acanthopore structure of *Amplexopora* and with 8 occurring in 2 mm. In vertical sections the immature region has diaphragms at intervals of 3 to 4 tube diameters, but in the mature zone 3 occur in one tube diameter.

Trenton (top of Hermitage): 2 miles west of Hartsville, Tenn.

Stellipora stipata Bassler, 1932 (pl. 11, figs. 3, 4)

Zoarium of incrusting lamellae with closely spaced star clusters in which the rays are narrow and leave little space between them for mesospores. In the genotype, *S. antheloidea* Hall, the clusters are much farther apart and each exhibits at its center a broad area of mesopores.

Trenton (top of Hermitage): 2 miles east of Cottage Home, Tenn.

Lioclemella bifurcata Bassler, 1932 (pl. 25, fig. 21)

Similar to the genotype, *L. ohioensis* Foerste, in zooecial structure and pointed base for articulation, but differing in that the zoarium bifurcates forming a distinct prong-shaped object; the zooecia are smaller (8 in 2 mm.) and the mesopores smaller and more numerous.

Richmond (Fernvale formation): 2½ miles northwest of Pulaski, Tenn.

Sowerbyella lebanonensis Bassler, 1932 (pl. 5, figs. 7, 8)

Brachiopod shell similar to *S clarksvillensis* and related species, but distinguished by the surface markings of very fine striae with 3 or 4 delicate ribs alternating with a single larger one, with cardinal extremities somewhat angular and the dorsal lamellae extending almost to the front of the valve. Surface flat to gentle convex.

Stones River (Lebanon limestone): Shelbyville, Tenn.

Rafinesquina hermitagensis Bassler, 1932 (pl. 12, figs. 5, 6)

Shell of *R. fracta* group but rather strongly convex in the median region

and without any geniculation. Differs also in the greater breadth of the valves in contrast with the length, an average shell being 22 mm. long by 30 mm. wide.

Trenton (near base of Hermitage): 2 miles south of Middleton, Tenn.

Strophomena odessae Bassler, 1932 (pl. 25, figs. 7–12)

Shell similar to *S. parvula* Foerste, but differing in its general proportions, smaller size, less angular cardinal extremities and finer surface markings.

Richmond (Fernvale formation): 2½ miles northwest of Pulaski, Tenn.

Tentaculites obliquus Bassler, 1932 (pl. 11, fig. 9)

Shell 8–10 mm. long, 1 mm. in greatest diameter, differing from other species of the genus in its slightly curved form.

Trenton (Hermitage formation): Danville, Ky.

Hormotoma columbina Bassler, 1932 (pl. 18, figs. 1, 2)

Shell similar to *H. major* Hall, differing in a smaller apical angle making it narrower and less robust. *S trentonensis* Ulrich and Scofield is also similar but is a shorter and more rapidly enlarging shell.

Trenton (Cannon limestone): 1 mile southwest of Franklin, Tenn.

Lophospira ulrichi Bassler, 1932 (pl. 17, figs. 5, 6)

Related to *L sumnerensis* Safford, but characterized by its low spire and unusual breadth. An average shell measures 22×22 mm.

Trenton (Cannon limestone): Near Hartsville, Tenn.

Ctenodonta hermitagensis Bassler, 1932 (pl. 11, figs. 7, 8)

Similar to *Ctenodonta pectunculoides* in general outline and dentition, but shell smaller and beak more produced with general surface marked by strong concentric lines.

Trenton (top of Hermitage): 3 miles east of Mt. Pleasant, Tenn.

Leperditia pondi Ulrich and Bassler 1932 (pl. 21, fig. 8)

A *Leperditia* with valves 16×12 mm., in length and height, characterized by the unusually equal curvature of both anterior and posterior ends. Surface smooth with a narrow rim and slightly developed ocular tubercle in the anterior dorsal third.

Trenton (Catheys formation): Nashville, Tenn.

Isochilina apicalis Ulrich and Bassler, 1932 (pl. 21, fig. 9)

An *Isochilina* with valves about 11 by 6½ mm. with eye tubercle close to the dorsal margin and a ridge almost one third the length of the valves just below the center and parallel to the hinge line.

Trenton (Catheys formation): Nashville, Tenn.

Isochilina columbina Bassler, 1932 (pl. 17, fig. 2)

A narrow, elongate *Isochilina* with dimensions of about 9×5 mm. with smooth surface, no marginal rim and a minute eye spot close to the anterior dorsal angles.

Trenton (Cannon limestone): Nashville, Tenn.

Isochilina nelsoni Ulrich and Bassler, 1932 (pl. 21, fig. 10)

Carapace equivalved, each valve about 13×7 mm., with surface smooth and a narrow rim along the free margins and with well developed ocular protuberance and accompanying nodes in the dorsal section.
Trenton (Catheys formation): Nashville, Tenn.

Aechmina longicornis Ulrich and Bassler, 1932 (pl. 27, fig. 6)

An *Aechmina* distinguished by the spine arising from the anterior half of the dorsal edge of the valves, which has a broad base and narrows to a point abruptly. A row of minute spicules occurs along the free margin of the valve. Valves excluding spine 0.9×0.5 mm.; spine 0.7 mm. long.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Ulrichia tenuimuralis Ulrich and Bassler, 1932 (pl. 27, fig. 14)

This species is particularly marked by the presence of a ridge close to the free margin and by a large oval node occupying the central part of the dorsal half of the valve. A smaller node anterior to this and the reticulate surface complete its characters. Valves 1 by 0.6 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Paracythere cornuta Ulrich and Bassler, 1932 (pl. 27, fig. 13)

A Cythere-like ostracod with a small but prominent node near the dorsal in the narrow anterior part, with a much broader posterior end, and with surface marked by concentric lines arranged around a small muscle spot posterior to the node. Valves 1 by 0.6. mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Monoceratina [Bursulella] tennesseensis Ulrich and Bassler, 1932 (pl. 27, figs. 11, 12)

A subtriangular-shaped ostracod with the apex of the triangle below and formed by the continuation of the ventral edge into a strong prominent spine. Valve excluding spine 1.5 by 1.1 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Beyrichiopsis modesta Ulrich and Bassler, 1932 (pl. 27, fig. 10)

This species differs from the genotype, *B. fimbriata* Jones and Kirkby, in that the surface markings are reduced to a single, small rounded post-median node, and that the frill extending from the edges of the valve is of more uniform diameter throughout. Valve with frill 1 by 0.6 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Beyrichiopsis pulchra Ulrich and Bassler, 1932 (pl. 27, fig. 1)

Distinguished from the associated *B. modesta* by its larger proportions, the very spinous surface, the small rounded subventral node and especially the double row of spines representing the frill paralleling the free edges. Valve measuring 1.8 mm. by 1 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Allostraca fimbriata Ulrich and Bassler, 1932 (pl. 27, fig. 5)

This, the only known species of the genus, is distinguished by its Cythere-like valves with a very broad subcentral eye or muscle spot, a distinctly

granular surface, and a prominent striated frill extending some distance beyond the free edges of the valves. Valve including frill 1.6 mm. by 0.8 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Paracythere granopunctata Ulrich and Bassler, 1932 (pl. 27, fig. 4)

Outline and surface markings of valve much as in *Allostraca fimbriata* except that the striated marginal rim of the latter is lacking. Valve 1.7 mm. by 1 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

Barychilina lineata Ulrich and Bassler, 1932 (pl. 27, figs. 2, 3)

Distinguished from other species of the genus by the delicate concentric lineate structure of the surface markings. Valves 1.6 mm. by 0.9 mm.
Kinderhook (Ridgetop shale): Mt. Pleasant, Tenn.

HYDROLOGY.—*Indian Hot Springs, Graham County, Arizona.*[1]

M. M. KNECHTEL, U. S. Geological Survey. (Communicated by O. E. MEINZER.)

The health resort known as Indian Hot Springs, at Eden, Arizona, is in sec. 17, T. 5 S., R. 24 E., about 8 miles northwest of the town of Pima, Arizona. (See fig. 1.) Here 5 thermal springs and a flowing well,

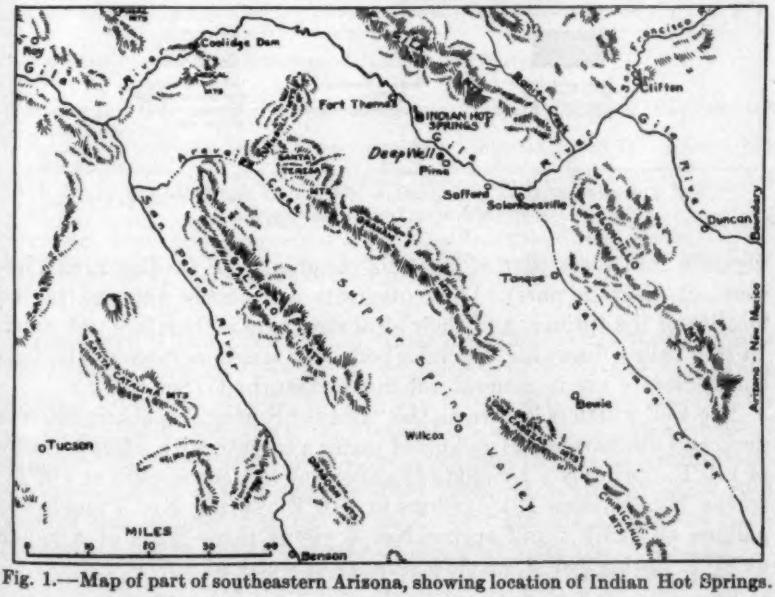


Fig. 1.—Map of part of southeastern Arizona, showing location of Indian Hot Springs.

[1] Published with permission of the Director of the United States Geological Survey. Received June 10, 1935.

having a combined discharge of about 320 gallons a minute, furnish water for general use at the adjacent hotel, for several Roman baths, and for a large swimming pool. Most of the water, however, escapes unused and runs in ditches directly to the Gila River. The elevation of the springs is about 2,820 feet above sea level.

The writer's study of Indian Hot Springs was made late in 1933 in connection with an investigation by the United States Geological Survey.[2]

The springs occur in a small reentrant in the face of a terrace that was carved during Pleistocene time out of lacustrine sedimentary

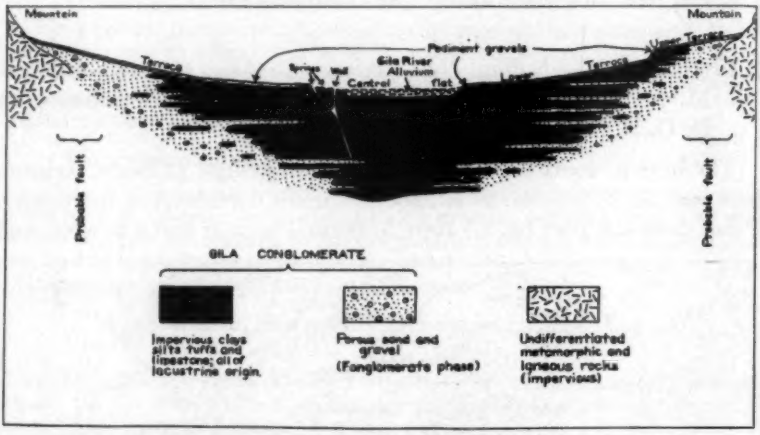


Fig. 2.—Interpretative cross-section of the Gila valley looking southeastward near Indian Hot Springs.

deposits that form part of the Gila conglomerate (in this area Pliocene, at least in part). These deposits are poorly exposed in the locality of the springs, and their local structure is therefore unknown. In this valley, however, the lake beds and fanglomerates of the Gila conglomerate are in general not much disturbed. (See fig. 2.)

The well which is known as the "Beauty Spring," is about 600 feet deep and discharges 156 gallons of water a minute with a temperature of 119°F. Spring No. 1 yields 145 gallons of water a minute at 116°F.; spring No. 2 yields 10½ gallons at 116°F.; spring No. 3 yields 6½ gallons at 118°F.; and spring No. 4 yields three-fifths of a gallon at 81°F. Spring No. 5 is a slow seepage of water at 107°F.

[2] KNECHTEL, M. M. *Geology and ground-water resources of the Gila and San Simon valleys, Graham County, southeastern Arizona.* U. S. Geol. Survey Water-Supply Paper (in preparation).

Samples of water were collected from the well and from 3 of the springs (Nos. 1, 3, and 4) and were analyzed by E. W. Lohr of the United States Geological Survey. The analyses, which are given in the accompanying table, show that all the samples contained a comparatively large amount of disolved solids, and that the different mineral constituents were present in each sample in about the same amounts and proportions. The amounts and proportions, moreover, were nearly the same as in a sample of water collected from a flowing

TABLE I.—ANALYSES OF WATERS AT INDIAN HOT SPRINGS AND NEAR PIMA, ARIZONA.[a]

	1	3	4	A	B
Calcium (Ca)	80	78	102	78	73
Magnesium (Mg)	9.4	9.0	12	10	7.2
Sodium and Potassium (Na+K) (calculated)	1,048	1,043	1,182	878	1,190
Bicarbonate (HCO_3)	100	98	114	106	96
Sulphate (SO_4)	405	404	518	357	419
Chloride (Cl)	1,420	1,410	1,580	1,190	1,610
Fluoride (F)	4.1	3.7	4.3	3.3	4.9
Nitrate (NO_3)	.0	.0	.5	.0	.0
Total dissolved solids (calculated)	3,016	2,996	3,455	2,568	3,351
Total hardness as $CaCO_3$	239	232	304	236	212

[a] Collected November 20–30, 1933. Analyzed by E. W. Lohr. Parts per million.

1. Spring No. 1; Indian Hot Springs, Eden, Ariz. Temperature 116°F.; discharge 145 gallons a minute.
3. Spring No. 3; Indian Hot Springs, Eden, Ariz. Temperature 118°F.; discharge 6½ gallon a minute.
4. Spring. No. 4; Indian Hot Springs, Eden, Ariz. Temperature 81° F; discharge 3/5 gallon a minute.
A. Drilled flowing artesian well ("Beauty Spring"); about 600 feet deep; Indian Hot Springs, Eden, Ariz. Temperature 119°F.; discharge 156 gallons a minute.
B. Drilled flowing artesian well 3,767 feet deep; 1 mile northwest of Pima, Ariz. Temperature 138°F.; discharge about 2200 gallons a minute.

artesian well with a discharge of about 5 second-feet of water, which was drilled unsuccessfully for oil to a depth of 3,767 feet at a point about 7 miles to the southeast, in the NW¼ NE¼ sec. 13, T. 6 S., R. 24 E., near the town of Pima. Furthermore, though these 5 analyses differ little from each other, they bear much less resemblance to the analyses of samples collected from 44 scattered wells and springs that receive water from sands and gravels at various horizons in the sedimentary deposits of this valley trough.

From the similarity in chemical composition of all the waters collected at Indian Hot Springs and from the Pima well, and the fact that the "Beauty Spring" well water and the water of the 3 springs

that flow most copiously show a variation in temperature of only 2 degrees, it may be inferred that all this water issues from the same horizon. The fact that the water of Nos. 4 and 5 is cooler, and that the water of the Pima well is 20 degrees hotter, than that of the "Beauty Spring" and Nos. 1, 2 and 3 may be explained as follows:

The temperature of spring No. 4 is 35 degrees lower than that of spring No. 1, which is less than 20 feet distant. As these springs yield water of similar chemical composition, which therefore probably comes from the same source, the difference in their temperatures is probably due to the great difference in their rates of flow, the water from spring No. 4 being cooled to a temperature lower than that of spring No. 1 because it rises more slowly to the surface. This implies, of course, that all or a part of the ascent is made through independent openings. This explanation also applies to the temperature of spring No. 5 which is 9 degrees lower than that of spring No. 1.

The temperature of the "Beauty Spring" well water and the water of the three principal springs at Indian Hot Springs averages about 117°F. If it is assumed that the water rises from a depth of only 600 feet, the depth of the "Beauty Spring" well, then unusual local thermal conditions must be invoked to explain the high temperature at this comparatively shallow depth below the surface. It is probable, however, that the water comes to the surface through fractures, perhaps caused by faulting, from an artesian source much deeper than 600 feet and that the well merely taps the upward-moving stream.

A depth-temperature study of field data collected by the writer on 78 flowing artesian wells in the Gila and San Simon valleys was made by H. C. Spicer, of the United States Geological Survey. His computations, which with one exception were based on wells ranging in depth from 100 feet to 1,450 feet, indicate a rise in temperature of 1°F. for each 57 feet of depth. A temperature of 135°F. for a depth of 3,540 feet, as computed from this gradient, checks surprisingly well with the measured temperature (138°F.) of the water flowing from the mouth of the deep well near Pima, most of which rises from a horizon at that depth. Most of the data on the depths of wells, and especially of the deeper wells, used in these computations, were reported to the writer from memory by various persons, some of whom had in turn acquired their information by hearsay. However, they are believed to be fairly reliable as a whole. The water temperatures were those observed by the writer at the mouths of flowing wells and probably are slightly lower than the temperatures of the water at depth. Some heat is lost by the water during its ascent to the surface,

especially in wells that have only small flows, and as many of the wells are not cased, the water issuing from a given well may come from several horizons at which the temperatures differ. In general, however, by far the greatest discharge is from the bottom of the well, and the cooling effect of water from higher levels is small. It is therefore believed that the average temperature, about 117°F., of the water from the 4 principal flowing units at Indian Hot Springs may be taken as a fair indication that the water rises from a depth of about 2,500 feet, this figure being derived from the plotted gradient as worked out by Mr. Spicer from the field data.

The mechanism that forces the water from this depth to the surface may be the same as that suggested to account for the pressure in the numerous artesian wells of this valley. It may be briefly stated as follows: The altitude of the water table in the porous gravels and sands (fig. 2) under the intake area along the margins of the valley is much higher than the surface of the central part of the valley. The pressure of the water in the marginal belts is transmitted underground to vertical openings, such as wells, in the dense lacustrine deposits of the central part of the valley. If the wells are at points where the surface altitude is sufficiently low, artesian pressure will cause discharge of water at their mouths.

BOTANY.—*Two new grasses from the United States and Mexico.*[1] JASON R. SWALLEN, Bureau of Plant Industry.

Two new grasses have recently been discovered in the United States and Mexico. The first is a new species of *Calamagrostis* collected in Jackson Co., Ohio, by Floyd Bartley and Leslie L. Pontius, and the second is a new species of *Bouteloua* found in Baja California by Forrest Shreve.

Calamagrostis insperata Swallen, sp. nov.

Perennis; culmi 85–95 cm. alti, glabri, e rhizomatibus erecti; vaginae glabrae, internodiis multo breviores; laminae planae, acuminatae, 10–22 cm. longae, 3–8 mm. latae, glabrae, marginibus scabris; ligula 5 mm. longa; panicula 12–14 cm. longa, ramis adscendentibus; spiculae appressae, 5–5.5 mm. longae; gluma prima lanceolata, 1-nervis; gluma secunda acuta, gluma prima paulo brevior, 3-nervis; lemma 4 mm. longum, 5-nerve, scabrum, apice erosum; pili calli lemmate duplo breviores; rachilla 0.5 mm. longa, pilis 2 mm. longis; arista 1 mm. supra callum inserta, geniculata, circiter 3 mm. longa.

Perennial; culms 85–95 cm. tall, erect, glabrous, with slender creeping rhizomes; sheaths much shorter than the internodes, smooth or scaberulous;

[1] Received June 14, 1934.

blades flat, acuminate, 10–22 cm. long, 3–8 mm. wide, glabrous, the margins scabrous; ligule membranaceous, about 5 mm. long; panicles 12–14 cm. long, the branches narrowly ascending, at least some of them naked toward the base, the lower ones as much as 5 cm. long; spikelets appressed to the branches, 5–5.5 mm. long; glumes unequal, somewhat keeled, scabrous on the keels, the first lanceolate, 1-nerved, the second acute, 3-nerved; lemma 4 mm. long, 5-nerved, scabrous, the narrow tip erose; callus hairs moderately dense, the lateral ones about half as long as the lemma, those on the back of the callus shorter; prolongation of the rachilla 0.5 mm. long, the hairs 2 mm. long; awn inserted about ¼ above the base, equaling the lemma, twisted below, geniculate, protruding from the glumes at maturity.

Type in the U. S. National Herbarium no. 1,611,713. Collected in Ofer Hollow, Liberty Township, Jackson Co., Ohio, August 1, 1934, by Floyd Bartley and Leslie L. Pontius.

This species is closely related to *C. pickeringii*, in which the spikelets are only 4–4.5 mm. long, the callus hairs are scant, and the rachilla hairs are only 0.5 mm. long.

Bouteloua annua Swallen, sp. nov.

Annua; culmi dense caespitosi, erecti, basi geniculati, 3–25 cm. alti, glabri, ramosi; vaginae internodiis breviores; laminae planae, acutae, 1–3.5 cm. longae, 1.5–2 mm. latae, pubescentes vel glabrae; ligula ciliata, 0.2 mm. longa; spicae 2–7, 1.5–2 cm. longae; spiculae 8–10 mm. longae, non pectinatae; gluma prima 1-nervis, 3.5–7 mm. longa, angusta; gluma secunda 6–9 mm. longa, 1-nervis, lata; lemma fertile, gluma secunda paulo longius, 3-nerve, 3-dentatum, dentibus 2 mm. longis; flos imperfectus pilosus, aristis 3 scabris.

Annual; culms densely tufted, erect or geniculate spreading at the base, 3–25 cm. long, glabrous with a single branch from the middle node; sheaths shorter than the internodes, glabrous; blades flat, 1–3.5 cm. long, 1.5–2 mm. wide, acute, pubescent on the upper surface or nearly glabrous; ligule ciliate, 0.2 mm. long; inflorescence as much as 8 cm. long with 2–7 rather distant ascending to spreading spikes, these falling entire; spikes distant, 1.5–2 cm. long, bearing 4–7 usually appressed spikelets, the rachis produced beyond the uppermost spikelet; spikelets 8–10 mm. long, appressed, green or usually purple, with one fertile floret and a 3-awned rudiment; glumes 1-nerved, more or less scabrous on the nerves, otherwise glabrous, the first 3.5–7 mm. long, very narrow, the second 6–9 mm. long, much broader, inclosing the florets; lemma a little longer than the second glume prominently 3-nerved, 3-toothed, the teeth about 2 mm. long, sparsely appressed pilose in lines especially close to the nerves, the callus densely pubescent; rudiment somewhat exceeding the lemma, the base stout, pilose, the awns scabrous.

Type in the U. S. National Herbarium no. 1,611,715. Collected 4 miles east of San Ignacio, Baja California, March 6, 1935, by Forrest Shreve.

This species belongs to the section *Atheropogon*, in which the spikes fall entire from the main axis and the spikelets are not pectinately arranged. Two other annual species, *B. alamosana* and *B. aristidoides*, belong to this group. The first differs from *B. annua* in having tuberculate hairy foliage,

and shorter spikes (10–15 mm. long), the spikelets closely appressed to the rachis. The second differs in having very slender spreading spikes with distant appressed spikelets. *B. annua* resembles *B. filiformis* in the form of the inflorescence, but that species is strictly perennial.

ZOOLOGY.—*A restudy of* Filariopsis arator *Chandler, 1931, with a discussion of the systematic position of the genus* Filariopsis *van Thiel, 1926.*[1] EVERETT E. WEHR, Bureau of Animal Industry. (Communicated by ELOISE B. CRAM.)

Van Thiel (1926)[2] proposed the genus and species *Filariopsis asper* for nematodes collected from the lungs of a "roaring monkey" (*Mycetes seniculus*) by Dr. C. Bonne in Surinam, British Guinea. Five years later, Chandler (1931)[3] described a second species *F. arator* for nematodes collected from the lungs of a South American monkey (*Cebus* sp.) by Dr. W. H. Taliaferro in Chicago, Illinois. Van Thiel referred the genus *Filariopsis* to the superfamily Filarioidea without assigning it to a family. Chandler, however, created the family Filariopsidae solely for its reception.

The present writer has made a restudy of the type specimens of *Filariopsis arator* Chandler, 1931. The results of this study have made it necessary to revise the original description of this species in certain respects. It has also made it possible to include a discussion of the cephalic papillae which have not been described in the literature.

RESTUDY OF FILARIOPSIS ARATOR

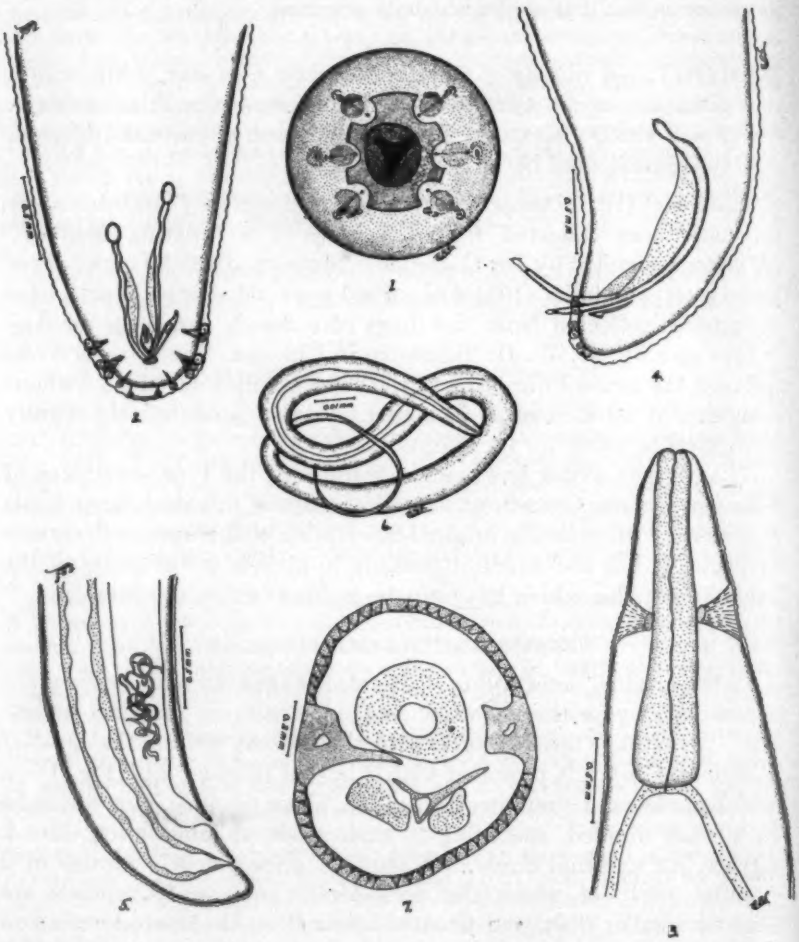
In the original descriptions it was stated that the oral opening was surrounded by 3 either "conspicuous" (*F. asper*) or "very inconspicuous" (*F. arator*) lips. According to the present writer, the head of *Filariopsis arator* is provided with 2 lateral trilobed lips (Fig. 1) on which are located a number of papillae. These papillae, numbering 14 in all, are divided, according to their mode of innervation, into 2 circles: An external circle of 8 papillae arranged in 4 groups of 2 papillae each, of which the dorsodorsals and ventroventrals are slightly smaller than, and situated internal to, the laterodorsals and lateroventrals; and an internal circle of 6 papillae, consisting of 1 papilla on the anterior border of each of the 6 lobes of the 2 trilobed lips. The amphids are located posterior to the internolateral papillae.

[1] Received June 7, 1934.

[2] VAN THIEL, P. H. *On some filariae parasitic in Surinam mammals, with the description of* Filariopsis asper *n. g., n. sp.* Parasitology 18: 128–136. 1926.

[3] CHANDLER, A. C. *New genera and species of nematode worms.* Proc. U. S. Nat. Mus., (2866), 78: 1–11. 1931.

The anterior extremity of *F. arator* (Fig. 3) was not figured by Chandler, but it is similar to that of *F. asper* as figured by van Thiel.



Figs. 1–7.—*Filariopsis arator*. Fig. 1.—Head, *en face* view. Fig. 2.—Male tail, ventral view. Fig. 3—Anterior extremity, dorsoventral view. Fig. 4.—Male tail, lateral view. Fig. 5.—Female tail, lateral view. Fig. 6.—First-stage larva. Fig. 7.—Cross section of body just back of excretory pore, showing excretory canal and the 2 subventral excretory cells on each side of it.

The clavate esophagus is short and muscular, and the broad, thick-walled intestine contains multinucleated cells. Two subventral ex-

cretory cells extending from the excretory pore posteriorly along each lateral side of the excretory canal were found in *F. arator*.

The caudal extremity of the male was described and figured by Chandler as lacking caudal alae and caudal papillae. Present observations indicate that alae are apparently absent or very poorly developed, and that there are 7 pairs of caudal papillae (Figs. 2 and 4) arranged in 4 groups and situated along the lateral and posterior margins of the body. The most anterior group on each side is composed of 2 papillae, the next of 3 papillae, and the last 2 groups 1 papilla each. Each papilla is joined to the body proper by a very weakly developed bursal ray. In the 2 male specimens available for study, the 2 approximately equal spicules do not appear to be joined together by a membrane, but each spicule is provided on its inner border with a wing-like membrane extending for about the middle two-thirds of its length. The so-called gubernaculum, boat-shaped in ventral view, appears in lateral view as an elongated cutinous plate with the distal end presenting a hook-like structure on its lower surface.

The vulva of the female of *F. arator* (Fig. 5) is located just anterior to the anal opening; that of *F. asper* occupies a similar position, according to van Thiel.

The first-stage larva (Fig. 6) is about 300μ long and 10 to 11μ wide, with the anterior end slightly attenuated and the tail very long, slender, and pointed at the tip. The esophagus extends about $\frac{1}{8}$ the total length of the body, with a swelling near the equator and another at the posterior end. In general body form, the first-stage larva of *F. arator* is similar to that of *F. asper*.

As a result of the present morphological study there seems to be no reason to believe, as Chandler did, that the 2 above species may eventually have to be placed in different genera. The male of *F. asper* has been described by van Thiel as possessing small caudal alae and 5 pairs of caudal papillae; it differs from that of *F. arator*, therefore, chiefly in the number of caudal papillae, since, according to van Thiel's figure of the male tail of *F. asper* the caudal alae, if present at all, are much reduced. Both species have similar spicules; *F. asper*, however, is described as having 2 gubernacula and *F. arator* as having only one.

SYSTEMATIC POSITION OF THE GENUS FILARIOPSIS VAN THIEL, 1926

Van Thiel did not state the reasons for his conclusion that the genus *Filariopsis* possesses filarioid affinities. As one of the characters of this genus, he mentioned the presence of microfilariae and, in all

probability, his belief that the young of this species were true microfilariae caused him to allocate this genus to the Filarioidea. None of the other characters of this genus mentioned by van Thiel, namely, (1) cuticle covered with conical protuberances, (2) situation of vulva close to anus, and (3) equality of 2 spicules, suggest filarioid affinity as the superfamily Filarioidea is defined today. Chandler debated whether to place the genus *Filariopsis* in the Spiruroidea or the Filarioidea, but finally decided tentatively to include it in the Filarioidea because of the absence of paired lips, the long and slender body, the position of the adults in the lungs of the host, and the presence of "microfilaria-like" embryos in the uteri, although, as he said, the genus differs from the other members of the Filarioidea in having the vulva near the anus, in the short muscular esophagus, and in the "non-coiled tail of the male."

As a result of his recent study of *F. arator*, the present writer has come to the conclusion that the genus *Filariopsis* belongs to the Metrastrongyloidea rather than to the Filarioidea. This conclusion is based on the following findings: The microfilaria-like embryos referred to by Chandler and van Thiel are not true microfilaria as they possess a distinct esophagus with 2 swellings, one near the equator and the other at the posterior end; the presence of 2 subventral excretory cells and of multinucleated intestinal cells in the adult (the present writer has demonstrated the presence of similar cells in *Metastrongylus elongatus*), and the character of the adult esophagus and the male tail. The presence of subventral excretory cells is a characteristic of the Strongylata, according to unpublished observations made by Dr. B. G. Chitwood, Zoological Division, Bureau of Animal Industry. The polymyarian condition of the somatic musculature, the absence of longitudinal cuticular markings, and the character of the esophagus of the first-stage larva tie *F. arator* to the Metastrongyloidea, and the much reduced bursa and bursal rays allocate it to the family Pseudaliidae and the subfamily Filaroidinae.

SUMMARY

A restudy of the type specimens of *Filariopsis arator* Chandler, 1931, has made it possible to add to the previous description of this nematode. From this new evidence and a critical analysis of the earlier descriptions of *F. arator* and *F. asper*, it is concluded that the genus *Filariopsis* belongs in the superfamily Metastrongyloidea, family Pseudaliidae, subfamily Filaroidinae.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

1073RD MEETING

The 1073rd meeting was held in the Cosmos Club Auditorium, October 27, 1934, President DRYDEN presiding. On a motion proposed by the Reverend HAWKESWORTH, which was unanimously approved, the recording secretary was instructed to convey to PAUL R. HEYL, a past president of the Society, the Society's condolence and deep sympathy because of the accident he suffered, October the twentieth.

The program consisted of two addresses upon the stratosphere flight of the *Explorer*.

L. J. BRIGGS: *The flight of the stratosphere balloon* Explorer.—The stratosphere flight on July 28 was sponsored by the National Geographic Society and the Army Air Corps. The great spherical balloon had a capacity of 3,000,000 cubic feet—three times as large as any balloon heretofore constructed and was designed to reach an altitude of 75,000 feet. The gondola, 100 inches in diameter, carried about a ton of apparatus and equipment.

The principal objectives were: (1) the measurement of the ionization produced by cosmic rays at different altitudes; (2) the directional effect of cosmic rays; (3) the spectrographic determination of the position of the ozone layer and the far ultraviolet spectrum of the sun; (4) the collection of air samples from the stratosphere; and (5) the determination of the relationship between altitude (computed from photographs with a vertical camera) and air density (computed from the observed pressure and temperature).

The ascent was made from a natural bowl in the Black Hills, chosen to provide protection from wind during inflation. All the apparatus functioned perfectly. The ascent was stopped at 61,600 feet because rips appeared in the bottom of the balloon. A slow descent was begun, and at 18,000 feet the gondola was opened. The descent continued at about 12 feet per second, but the tearing of the lower fabric increased until finally the entire bottom of the balloon below the catenary tore away. The flight personnel decided to try to land the balloon as a parachute, but at 3,000 feet the balloon suddenly disintegrated. Major Kepner, Capt. Stevens, and Capt. Anderson took to their parachutes and the gondola went crashing into the ground.

Reliance had been placed largely on photographic recording of the observations. All cameras were broken open by the impact, but the films which remained tightly rolled, although badly light-struck, were found to be legible up to the highest altitude of the flight. The sun spectrograph, suspended below the gondola, had been cut loose before the balloon failed and landed safely on its own parachute. Consequently, much information was gained from the flight, despite its unfortunate ending. (*Author's abstract.*)

L. B. TUCKERMAN: *Technical difficulties in stratosphere ballooning.*—The technical difficulties in stratosphere ballooning in contrast to ordinary ballooning depend upon the greatly increased pressure differences encountered. First, the decrease in density of the air, which is on the average somewhat more than ½ for each 20,000 feet of altitude, requires very much larger balloons to carry the same load. The necessity of maintaining sufficient air

pressure to keep the passengers alive increases the necessary dead weight and still further increases the necessary size of the balloon.

The large size makes net balloons impractical so that in stratosphere balloons, as in racing balloons, the gondola is hung from a catenary suspension band instead of from a net. The great size, however, prevents the use of an inflation net, as is customary in racing balloons. This is replaced by an upper catenary band controlled by yaw ropes during inflation.

The great decrease in pressure also makes it impractical to fill the balloon completely at the ground level. The gas in the balloon would expand somewhere between 22 to 28 times its volume in rising 75,000 feet instead of approximately twice as it would if the balloon were to rise to only 20,000 feet. It is customary to provide for a loss of approximately ½ of the gas volume at the maximum so that the balloon at the take-off is only approximately 1/15 full.

The technique of folding and inflating the balloon must therefore be such as to allow the balloon to fill out during the ascent without undue stresses occurring in the fabric. Two techniques have been used.

In the open bottom technique the requisite amount of hydrogen is put in the bag and air allowed to enter as the yaw ropes are eased off, so that at the time of take-off the air inside the lower portion of the bag is in pressure equilibrium with the air outside. This facilitates a smooth arrangement of the bag but has the disadvantage of the constant menace of a hydrogen-air explosion.

In the closed bottom technique no air is admitted, so that the whole lower portion of the balloon is collapsed and held tightly together under the excess pressure of the outside air. This makes it difficult to arrange the folds of the balloon smoothly, especially the lowest portion between the suspension ropes. To avoid this difficulty in the *Explorer* the lowest portion was folded inside the portion above the suspension band, making the inflation of the balloon much easier. Unfortunately this allowed the transmission of excessive local stresses from the outer fabric to the inner fabric through the shear resistance of adhesions. These stresses produced multiple radial tears in the lower portion of the balloon. In future flights, this difficulty can be avoided in several ways, the particular method to be used depending upon estimates of cost.

The *Explorer* descended as an open bottom balloon. The explosion which destroyed the balloon at about 2500 feet from the ground emphasizes the danger inherent in the open bottom technique.

With present ballooning technique it does not seem feasible to reach altitudes much above 90,000 or perhaps 100,000 feet. Rough estimates indicate that to carry the scientific apparatus and the gondola of the *Explorer* to a height of 100,000 feet would require a balloon of over 25,000,000 cubic feet and that over 7500 lb. of ballast would need to be retained at its maximum altitude to bring the balloon down safely.

To reach 150,000 feet the estimates give the fantastic figures of over 2,000,000,000 cubic feet, a balloon of over 1500 feet in diameter, carrying over 125,000 lb. of ballast. These estimates, based upon present balloon practice and our imperfect knowledge of the atmospheric conditions above 75,000 feet, can of course only indicate orders of magnitude. However, no feasible modifications in balloon technique seem to offer materially smaller figures. (*Author's abstract.*)

There was a joint discussion of these addresses participated in by Messrs. HAWKESWORTH and W. P. WHITE.

1074TH MEETING

The 1074th meeting was held in the Cosmos Club Auditorium, November 10, 1934, President DRYDEN presiding.

Program: R. E. GIBSON: *Compressibility of aqueous solutions.*—Measurements of the compressibility of aqueous solutions made at the Geophysical Laboratory were presented and these were correlated by means of the following relation: the change in volume upon compression of an aqueous solution is equal to the sum of two volume changes: first, that of the pure solute under the externally applied pressure, and second, that of pure water initially under a so-called *internal pressure* when subjected to a further increase of pressure equal to the applied pressure on the solution. The *internal pressure* is proportional to the volume concentrations of the water and solute. (*Secretary's abstract.*)

Discussed by Messrs. HAWKESWORTH, MOHLER, WHITE, KRACEK, ADAMS, HECK, and BRICKWEDDE.

L. R. MAXWELL: *Electron diffraction and its application to the structure of molecules.*—Recent advancements in the field of electron diffraction were presented. The experiments on the diffraction of electrons from thin metallic foils and diatomic gases were shown to be in agreement with the theories of electron scattering. This justifies the use of electron diffraction for the determination of the structure of complex molecules. Examples of this kind were given for NO_2 and N_2O_5. From a treatment of the molecule 1, 2 diiodobenzene clear physical evidence was shown for the phenomenon of *steric hindrance.* The relation between the C-C distance and strength of bond was given and also the values of the C-C distances characterized by aliphatic and aromatic compounds. Brief summary of all structure determinations by electron diffraction was presented. (*Author's abstract.*)

Discussed by Messrs. GIBSON and BRIGGS.

Informal Communications: L. B. TUCKERMAN.—Debye and Sears showed that standing high frequency acoustic waves in a transparent medium acted like a grating. Schaefer and Bergmann set up waves simultaneously in three different directions mutually at right angles, thus setting up a *space lattice* of concentrations of stress. Passing ordinary light waves through the medium either liquid or solid, produces a *Laue pattern.* Slides copied from the following published articles were shown: C. Schaefer u. L. Bergmann: *Laue-Programme mit optischen Wellen.*—Sitz. Ber. Preuss. Akad d. Wiss., **X**: 152–153, March 22, 1934, and *Neue Interferenzerscheinungen an schwingenden Piezoquarzen.*—l. c., **XIII–XIV**, April 26, 1934. (*Author's abstract.*)

W. J. HUMPHREYS and H. L. DRYDEN.—This dealt with the orientation of falling hexagonal, columnar crystals of ice in air, that is, with the question as to whether the crystals falling with the long axis of the column horizontal fall with the long diagonal of the hexagon horizontal or vertical. The solar halo called the Peary Arc is produced by crystals oriented with the long diagonal of the hexagon horizontal. Wind tunnel tests on a wooden model showed that the most stable position for the model was that with the long diagonal in a direction corresponding with the vertical. (*Secretary's Abstract.*)

Discussed by Messrs. NcNISH and MAXWELL.

1075TH MEETING

The 1075th meeting was held in the Cosmos Club Auditorium, November 24, 1934, President DRYDEN presiding.

The program consisted of three papers dealing with different phases of

Finding the fact about strong earthquake motion with special relation to its effect on structures.

N. H. HECK: *Outlining the problem.*—In designing buildings to resist earthquakes some assumptions have been made which should be tested in the light of present knowledge. The adoption of an acceleration of 0.2 or 0.1 g. as a true measure of a great earthquake was shown to be merely a guess that works for reasons not directly connected with the earthquake. The range of 0.5 to 2.5 secs, as that of dangerous periods of buildings, with the inference that other periods are not dangerous, was shown to be probably due to the fact that this range covers the periods of most of the buildings in Japan where the idea was suggested and the effect is simply resonance.

Earthquakes have a very wide range of periods and it is not possible to design a building to escape a period which may set it into resonance. However if the ground can be set into vibration in its own period then there will be prevailing periods in any earthquake which can and should be avoided. Observations of ground period at Göttingen, Germany, by means of a machine which sends controlled vibrations through the ground showed that definite periods exist. The results were checked by observations of seismograms from earthquakes a few hundred miles away, by explosions and by study of microseisms.

The investigations in California include strong motion measurements which have been made as the result of eight earthquakes in California and two in Nevada. In the case of one of the latter as well as in one in Panama the instrument was about 200 miles from the earthquake epicenter. The instruments are placed in the basements of buildings, in the top or elsewhere in buildings. Accelerographs and displacement meters are operated together. The result is a wide range of records obtained under varying conditions.

The investigations also include measurement of vibration periods of buildings, tanks, bridge piers and dams; the measurement of ground periods by controlled vibrations and by analysis of earthquake records, including strong motion; the study of earthquake damage in the Long Beach earthquake of March 10, 1933; and the development and construction of instruments needed to accomplish these purposes.

The program was developed at a series of conferences in California last spring which resulted not only in an effective and broad plan, much of which is now in operation, and also arrangements for application of the information to building design, a field into which the Coast and Geodetic Survey does not enter. The organizations represented include the organizations of structural, civil and mechanical engineers, and several universities interested in the work. (*Author's abstract.*)

H. E. MCCOMB: *Development of instruments.*—Instruments which have been developed elsewhere for use in areas frequented by strong earthquakes were found to be unsuitable for the particular problems in hand. Hence, the program called for much preliminary testing of crude designs, preparation of plans and specifications for completed instruments and equipment on a quantity basis and study of all other phases of the project which would involve continuous operation and maintenance of a large number of instruments at great distances from Washington. As a result of rather intensive application the Coast and Geodetic Survey had in operation on the Pacific Coast, thirty-three 3-component accelerographs, six displacement meters and eleven low-magnification mechanical seismographs. One accelerograph

is also in operation in the Canal Zone. In addition to the seismographic equipment three interferometric tiltmeters, for use in studying pre-seismic tilting effects of the ground, have been installed in the vicinity of well-known faults.

Instruments and other accessories have been altered, in many cases, quite radically, when, after extensive tests, it has been proved that much would be gained in simplicity, convenience of adjustment and interchangeability of parts without sacrificing accuracy or reliability. The most radical change was from quadrifilar accelerometer suspension to pivot and helical spring suspension. In addition to this improvement there has been designed a low-magnification attachment for the accelerometers which permits any single unit to record at normal magnification and also simultaneously at about $\frac{1}{6}$ normal on the photographic recorder, the spots being in the same phase and free from parallax. Actual records obtained at Long Beach show that this reduced magnification should simplify interpretation of the main record and will insure full registration of the most severe earthquakes.

Instruments, resembling in many respects, standard Wood-Anderson seismometers, have been constructed for use in studying building vibrations. Shaking tables for use in testing the vibration meters have been designed and are under construction. At Pasadena, Dr. Benioff of the Carnegie Institution of Washington is cooperating in the program by constructing some electromagnetic seismographs for use in studying effects of aftershocks. He has also constructed a series of simple recording pendulums of different natural periods operating side by side. At Stanford University, Dr. Jacobsen has constructed a device for placing buildings or the ground into vibration for convenient study by vibration meters.

About 40 slides were shown and several instruments of recent design were exhibited. (*Author's abstract.*)

FRANCK NEUMANN: *Analyzing the records.*—The engineer expects about five different classes of data as a result of the present seismological investigations now being undertaken by the U. S. Coast and Geodetic Survey in California. They are: (1) Periods of earthquake waves, (2) Natural vibration periods of geological formations in seismic areas, (3) Periods of buildings, (4) Motion of the ground during an earthquake in terms of acceleration and displacement, and (5) Motions of the upper floors of structures during an earthquake.

Periods of earthquake waves are obtained by direct measurement on strong motion seismograms, as the pendulum of a seismograph is forced to swing in the period of the wave, but amplification on the record varies greatly, depending upon the ratio of the earth wave period to the pendulum period. The periods of geologic formations are observed by studying the dominant periods on seismographic records, or by forcing the ground to vibrate artificially with an agitator or unbalanced wheel. In the latter case the largest amplitudes are recorded on a sensitive seismograph when the period of the agitator tunes in with the natural period of the formation. Building periods are obtained by observing with a sensitive seismograph the natural swaying of a structure caused by wind or an agitator. The period of a building is dependent not only on the physical properties of the structure itself, but also on a foundation factor or *hinge* effect. J. Creskoff has shown theoretically that the fundamental period and its ratio with the first overtone vary with the type of foundation. Period observations, therefore, furnish directly information which is necessary in computing the period of a structure. The aim of the engineer is to design structures which

will not tune in with the most prevalent earth wave periods during an earthquake, or with the natural vibration periods of the geological formations on which they are built.

Ground movements during an earthquake are measured with displacement meters and accelerometers. The problem of analyzing the records is greatly simplified by assuming sustained simple harmonic motion of the earthquake waves over small portions of the record, and by using a so-called harmonic magnification curve. The latter shows the ratio between the displacement of a seismograph pendulum (with respect to the moving ground) and the actual displacement of the ground itself. In a displacement meter the earth wave periods are relatively short with respect to the pendulum period so that the mass remains almost fixed in space while the ground moves beneath it. In the accelerometer the harmonic magnification terms become practically equal to the ratio of the square of the pendulum period over the earth wave period, and when this is substituted in the expression for simple harmonic acceleration, the earth wave periods are eliminated, showing that acceleration is independent of the earth wave period. Pendulum periods in an accelerometer must be less than one-third of the periods of the earth waves to be measured.

Building movements are measured in the same manner as ground movements. Experience teaches that the top of a moderately tall building may sway through seven times the amplitude of the ground during an earthquake.

When simple harmonic motion cannot be assumed the records must be integrated to obtain true ground motion. Work has been done in double integrating acceleration curves to obtain displacement with some success, but the deflections of the acceleration trace are so small for the longer period earthquake waves that the task becomes extremely difficult. The accelerogram is magnified about eight times by means of a lantern projector and the image traced with a pencil on coordinate paper. The average ordinate is tentatively accepted as the axis and the integration carried through. From the dimension of the bend in the resulting double integrated curve, the errors in the acceleration and velocity curves can be computed, and the work is then repeated so the final curve lies along a straight axis. The work of integration is done on standard adding machine. (*Author's abstract.*)

There was a joint discussion of the three papers participated in by Messrs. H. L. CURTIS, MCNISH, HECK, HUMPHREYS, DRYDEN, BRICKWEDDE, and WENNER.

1076TH MEETING

The 1076th meeting, constituting the 64th annual meeting, was held in the Cosmos Club Auditorium, December 8, 1934, President DRYDEN presiding.

The treasurer reported receipts of $3669.47 including the payment of a real estate note amounting to $1500.00, and expenditures of $2333.40 including the purchase of a bond amounting to $1024.82, leaving a cash balance of $1336.07. The treasurer's report showed an active membership of 299.

The secretaries reported that the following new members were elected during the year: A. K. BREWER, C. F. BROWN, P. CHRZANOWSKI, W. E. DEMING, J. M. FRANKLAND, R. E. GEBHARDT, L. C. GOTTSCHALK, R. B. HOBBS, H. H. HOWE, E. A. JOHNSON, R. T. MILNER, M. M. MUNK, J. A. PLUGGE, P. A. SMITH, R. WIEBE, P. H. WILLIAMSON, and O. R. WULF.

The following deaths were reported: R. Y. FERNER, G. O. SQUIER, and G. F. STROHAVER.

The following officers were declared elected for the year 1935: *President*, O. H. GISH; *Vice Presidents*, N. H. HECK and F. WENNER; *Recording Secretary*, L. R. HAFSTAD; *Treasurer*, R. E. GIBSON; *Members-at-large of the General Committee*, F. G. BRICKWEDDE and H. E. MCCOMB.

During the year the fourth Joseph Henry Lecture, in memory of the first president of the Philosophical Society, was given by Professor OSWALD VEBLEN of the Institute for Advanced Study, Princeton, N. J.

At the conclusion of the business part of the program, Mr. W. J. HUMPHREYS presented a paper, illustrated by slides, entitled *Tall tales of the prairie twister*. Following the presentation of the paper there was a discussion participated in by Messrs. DRYDEN, CURTIS, HECK, HAWKESWORTH, WAIT, MARIS, ROESER, HAZARD, SHEPHERD, SILSBEE, TUCKERMAN, GISH, and four others unknown to the secretary.

(*Author's abstract*).—The tornado, a violent rotating wind starting at the cloud level and burrowing down to the earth, occurs more frequently in the United States, mainly in the Mississippi Valley, than in any other country. It appears to be caused by vertical convection at the boundary between oppositely-flowing masses of air, turns counterclockwise in the Northern Hemisphere, clockwise in the Southern, and leaves a sharply-defined path of destruction.

It is exceedingly noisy, even when away from contact with the earth, and its power of destruction, owing partly to the velocity of the wind and partly to the decrease of pressure in the vortex, is astonishingly great. The dominant effects of the tornado are wreck and ruin, but also many surprising things occur. Trees, houses, and bridges may be utterly demolished, and yet out from the welter of destruction delicate and easily breakable things may be carried miles away without harm.

In one case a steel beam, one of the supports of a bridge, was torn from its setting and hurled an eighth of a mile where, end on, it struck a tree and penetrated clear through it, 20 feet above the ground. Amazing weights are lifted, concrete posts pulled out of the ground, and even locomotives and heavy steel coaches thrown from their tracks. Planks are stuck into the ground like fence posts, driven through trees and even, in one case, through the thick steel web-plate of a bridge.

And sometimes there seems to be a bit of grim humor in what the tornado does. It sticks straws end on into trees and leaves us the puzzle of explaining how; pulls the wool from a sheep's back with never a break in his skin; makes boastful roosters silent members of the flock, with every feather gone; and a man, woman or child it may leave unscathed on a neighbor's lawn with never so much of the conventional dress as even a chemise or shirt.

Unfortunately the great majority of the tales of the tornado, the smallest but most violent of all storms, are tales of tragedy; yet some are humorous, even ludicrous, while many are indeed *tall*, in the sense of surprising.

F. G. BRICKWEDDE, *Recording Secretary*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

Biological Survey's Golden Jubilee.—Fifty years ago, in 1885, a modest appropriation of $5,000 by Congress for the promotion of "economic ornithology," marked the first beginnings of the activities that have come to be centered in the Biological Survey of the U. S. Department of Agriculture. Upon the recommendation of the American Ornithologists' Union, Dr. C. HART MERRIAM, physician and naturalist, was appointed head of the new project, with which he served until his retirement in 1931. The project was first established as a branch of the Division of Entomology. The year following, with a doubled appropriation, it achieved independent status as the Division of Economic Ornithology and Mammalogy. In 1896, the name was changed to Division of Biological Survey, and in its twentieth anniversary year, 1905, it received its present title of Bureau of Biological Survey.

Secretary HENRY A. WALLACE and JAY N. DARLING, chief of the Bureau, were among the speakers at the thirteenth annual convention of the Izaak Walton League of America in Chicago last spring. A number of members of the Survey also participated.

AMOS B. EMERY has been designated to coordinate and direct the work of some 25 CCC camps on refuges administered by the Survey.

By Act of Congress, approved by the President on June 15, any person is authorized to purchase migratory bird hunting stamps. A waterfowl hunter must have in possession a stamp that has been validated by writing his signature across its face. The same Act carried an appropriation of $6,000,000 to be used for the acquisition of lands for refuge purposes. Funds from the Emergency Act of April 8, 1935, may also be allocated by the President for refuge-acquisition purposes.

Food and Drug Administration.—Two Doctors NELSON have been appointed as chiefs of new divisions of the Food and Drug Administration, Dr. E. M. NELSON as chief of the Vitamin Division and Dr. ERWIN E. NELSON as chief of the Pharmacological Division. The Department of Agriculture announced that each is now assembling a staff taken in part from older units of the Department and in part recruited from specialists in the sciences involved in the work of the new divisions. The Vitamin Division will check the claims and help establish standards for food and drugs for which claims of vitamin potency are made. The Food and Drug Administration has been doing some routine work of this sort, but it has been inadequate to meet the growing need. The Pharmacological Division in addition to more comprehensive testing of certain medicinal products, will pay particular attention to several relatively new fields of work—the testing and standardization of glandular preparations put on the market in recent years, investigations of the effect of poisons and impurities present in foods, and testing of the effects of new synthetic chemicals used in foods and medicines. Of the poisons and impurities, the question of spray residues on fruits and vegetables is now most pressing. In regulating interstate commerce in sprayed products the department is urgently in need of more positive and authoritative guides to safe practice.

National Park Service.—Chief Naturalist EARL A. TRAGER during August

made a geological inspection tour of the states north of the District of Columbia. Included in his itinerary were visits to several of the state parks in Pennsylvania and New York, the Acadia National Park in Maine, and a tour of the section which would be traversed by the proposed Green Mountain Parkway.

VINCENT W. VANDIVER of Missouri has received appointment as regional geologist for the National Park Service. His headquarters will be Washington, D. C., and he will probably be assigned to the region including the states of Nevada, Arizona, New Mexico and Utah. Before coming to the Park Service he was a member of the Missouri Geological Survey.

SUMNER M. ANDERSON of New York and Dr. ROY A. WILSON of Oklahoma have also been assigned to work in connection with the Service's geological program. Mr. ANDERSON has made extensive geological studies in South America, and the middle section of the United States. Dr. WILSON has served as professor of geology at the University of Oklahoma. It is planned to assign him to the Rocky Mountain region.

National Bureau of Standards.—Dr. MORTON G. LLOYD attended sessions of the International Electrotechnical Commission at the Hague and Brussels June 18 to 27, and sessions of the International Commission on Illumination at Berlin and Karlsruhe July 1 to 10. He also attended the National Electrical Convention of Great Britain held at Bournemouth early in June.

Dr. F. C. BRECKENRIDGE attended the sessions of the International Commission on Illumination at Berlin and Karlsruhe July 2 to 10 and is spending some time in Europe inspecting facilities for air transport, particularly lighting and light signals. Mr. BRECKENRIDGE is in charge of a group of men engaged on study of such problems on behalf of the Bureau of Air Commerce and the Navy Department, and the primary purpose of his trip is to obtain information of value to those organizations.

Dr. LYMAN J. BRIGGS, director of the National Bureau of Standards, presided at a meeting in Akron, Ohio, on July 24 of a special board of inquiry called for the purpose of ascertaining the cause of failure of the stratosphere balloon Explorer II. The board is composed of representatives of the National Geographic Society, Army Air Corps, and members of various scientific societies and the National Bureau of Standards.

Department of Terrestrial Magnetism.—Dr. E. H. BRAMHALL, physicist of the Byrd Antarctic Expedition II, has been appointed professor of physics at the University of Alaska to succeed Prof. VERYL R. FULLER, who died suddenly on May 30. Since June 10, Dr. BRAMHALL has been engaged at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in making the final comparisons with standards and in determining constants and corrections for the instrumental outfit used during the Byrd Antarctic Expedition II, and in the development of the technique for the ionospheric program at College, Alaska, which he will continue when he takes up his duties there.

Dr. J. BARTELS, professor of physics at the Forstliche Hochschule, Eberswald, Germany, and lecturer in geophysics at the University of Berlin, and Dr. S. CHAPMAN, chief professor of mathematics at the Imperial College of Science and Technology, London, England, both research associates of the Carnegie Institution of Washington, are spending the summer in America, chiefly at the Department of Terrestrial Magnetism, engaged on research problems in geophysics.

News Briefs

By executive order of the President, the Science Advisory Board has been continued until December 1, 1935.

A device for the rapid sectioning of hair, wool and other fibers, to facilitate microscopic examination, has been invented by Dr. J. I. Hardy of the Bureau of Animal Industry, U. S. Department of Agriculture. In addition to its primary usefulness in fiber technology, it may find employment in the Federal Bureau of Investigation, U. S. Department of Justice.

The Smithsonian Institution has published a description of the Badianus Manuscript (Vatican Library), which is the earliest known American Herbal. It was written in Mexico City in 1552, in Aztec, by an Aztec Indian student at the College of Vera Cruz, and was translated into Latin by another Aztec Indian.

Obituary

Marion Dorset, chief of the Biochemic Division, Bureau of Animal Industry, U. S. Department of Agriculture, died at his home in Washington, D. C., July 14, 1935, after a brief illness. He was born December 14, 1872, in Columbia, Tennessee. After graduating from the University of Tennessee in 1893, with the degree of Bachelor of Science, he attended the University of Pennsylvania for a year. Dr. Dorset then entered the U. S. Department of Agriculture as assistant chemist. While there he continued his scientific education at George Washington University, receiving the degree of Doctor of Medicine in 1896. Eight years later he became chief of the Biochemic Division of the Bureau of Animal Industry, a position he held until his death. The honorary degree, Doctor of Veterinary Medicine was awarded in 1915 by Iowa State College.

Although known especially for his research studies of hog cholera and his discovery of an effective preventive serum treatment for this devastating scourge, Doctor Dorset made many other important scientific contributions covering a wide field. They included research studies on the tubercle bacillus, keeping qualities of meats, composition and nutritive value of various meats and meat food products, the development and testing of disinfectants and dipping preparations, biological products used against animal diseases, research in dairy bacteriology, and extensive related work. Dr. Dorset organized the Federal inspection of establishments licensed to manufacture serums, viruses, toxins, and related veterinary biological products. He likewise formulated the laboratory procedures in the administration of the Federal Meat Inspection Act. As its first chairman Dr. Dorset organized the Insecticide and Fungicide Board and in collaboration with the other members initiated enforcement of the Insecticide Act of 1910. In addition to the Washington Academy of Sciences he was a member of the American Chemical Society, the Society of American Bacteriologists, the American Public Health Association, a fellow of the American Association for the Advancement of Science, and an honorary member of the American Veterinary Medical Association.